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The Effect of Fire Intensity on Understory Vegetational Development

THE EFFECT OF FIRE INTENSITY ON UNDERSTORY VEGETATIONAL DEVELOPMENT

by

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ABSTRACT

The results of a study on the effect of fire intensity on understory vegetation in seral stands of ponderosa pine are presented. Vegetational recovery for two burn intensities and unburned sites were compared. The results suggest that a change in the understory dominance structure following underburning is related to the amount of duff consumed by the fire, and independent of fire line intensity and flame length. A significantly greater proportion of duff was removed on high intensity sites (80%) than on low intensity sites (40%), however. The variation in fire line intensity was great, with some overlap. Fire line intensity ranged from 30 to 3034 kcal/m-s on high intensity sites and from 25 to 194 kcal/m-s on low intensity sites. Flame length ranged from 0.1 to 1.7 m on both high and low intensity sites. Graminoid canopy coverage was lowest on high intensity sites. The reduction was apparently the result of prolonged smoldering of the duff layer. There was no significant difference in coverage among treatments for shrubs or forbs. A significant change in frequency among treatments was noted for eleven species.

INTRODUCTION

Prescribed burning can be an effective tool in the management of seral stands of ponderosa pine (*Pinus ponderosa*). Fire may be used to reduce fuel loading, thin thickets of saplings, create mineral seedbed for seed germination, remove shade tolerant trees from the understory, prune the lower branches from the trees, and reduce needle litter on the soil surface (Biswell et al. 1973). Prescribed burning can also be an effective tool for understory vegetation management. Yields are dependent on the percent overstory canopy closure and the amount of accumulated litter (Wright 1978). Different intensity fires may be used to manipulate the various above effects. The effect fire intensity may have on understory development has not been previously studied. Thus, the objective of this study was to determine the effect fire intensity has on early vegetational development in the Douglas-fir/ninebark (*Pseudotsuga menziesii/Physocarpos malvaceus*) habitat type (Daubenmire and Daubenmire 1968).

LITERATURE REVIEW

In the northern Rocky Mountains, vegetational recovery in response to fire that removes the overstory is variable, although the eventual outcome is relatively consistent (Lyon and Stickney 1976, Cattelino et al. 1979). Early successional seres apparently lack the consistency and predictability exhibited by older seres (Cattelino et al. 1979). In general, however, succession proceeds in a more or less orderly sequence from herb dominated communities, to shrub dominated communities, and finally, tree dominated communities (Larsen 1929, Lyon and Stickney 1976). The number of years the first two phases dominate the site is dependent on the severity of the disturbance (Zamora, in press).

In Douglas-fir (*Pseudotsuga menziesii*) habitat types, fire promotes the establishment and growth of ponderosa pine (Wright 1982). Seral stands of ponderosa pine reproduce best in clearings (Schubert 1974) with a mineral soil surface (Schultz and Biswell 1959). In the absence of fire, Douglas-fir may supplant ponderosa pine and become the overstory dominant

(Daubenmire and Daubenmire 1968). Ponderosa pine is very fire resistant because of its thick bark, deep root system, and moderately high, open crown (Flint 1925).

Many shrubs regenerate above ground tissue from underground organs following fire in the Douglas-fir/ninebark habitat type (Lyon and Stickney 1976). Root crowns and rhizomes are two adaptations that enable shrubs to survive fires. Over fifty percent of all shrub species in the northern Rocky Mountains regenerate from root crowns (Lyon and Stickney 1976). Some shrubs also recolonize burned sites with dormant, fire-activated seeds (Leege 1968, Lyon and Stickney 1976).

Several studies have documented shrub response to fire. In northern Idaho, fall burning stimulated more shrub resprouts than spring burning, but spring burning did not appear to adversely effect vegetative reproduction (Hooker 1972). A recent northern Idaho study showed that shrubs dominate the grand fir/myrtle-boxwood (*Abies grandis/Pachistima myrsinites*) habitat type (Daubenmire and Daubenmire 1968) from about eight to twenty-seven years after burning (Zamora, in press). In southern Idaho, shrub cover was ten times the preburn level seven years after burning (Lyon 1971).

The most important fire survival mechanism for on-site herbaceous plants is the rhizome; off-site species recolonize burned areas by wind-borne seed (Lyon and Stickney 1976). In southern Idaho, Lyon (1972) found that herbaceous cover was nearly as dense one year after burning as in unburned areas. In the grand fir/myrtle-boxwood habitat type, herbaceous species dominated the site from the first through the eighth year after burning (Zamora, in press). Keown (1978) summarized the fire adaptations and post-fire responses for specific herbaceous and shrub species.

METHODS

The study was conducted on the Coeur d'Alene Indian Reservation in Benewah County, Idaho. The elevation of the study area was approximately 880 m above sea level on gently rolling hills. Average annual precipitation is 560 mm, the majority of which

falls primarily from October to March. The study area has been previously described by Bakken (1981).

Sampled sites were limited to the Douglas-fir/ninebark habitat type. The sites were dominated by seral stands of ponderosa pine with an understory of shrubs and perennial graminoids. The sites were selectively logged 3 different times at about 10-year intervals; the last time in 1977. Between 11 and 35 percent of the overstory basal area was removed from all of the sites. The amount of basal area removed on each site was proportional to the amount removed from the entire stand. Before forest management activities including fire suppression, the sites had a mean fire-free interval of approximately 22 years. However, the sites have not burned for about 44 to 62 years. Grazing by domestic livestock has not occurred on the sampled sites for at least 30 years.

A split-block design was used to test the null hypothesis that there is no difference in understory species cover or frequency among treatments. Three treatments were identified: unburned control, low intensity, and high intensity burns. Three locations were subdivided into nine 0.2 to 1.0 ha units and burned under varying intensities during the fall of 1978. Three replications of high and low intensities and unburned sites were sampled within each location. There was a large degree of variation (C.V. = 143.1) between fire treated sites, with some overlap in intensity. Fire line intensity (Rothermel 1972) was significant ($P < 0.05$), and ranged from 30 to 3034 kcal/m-s on high intensity sites and from 25 to 194 kcal/m-s on low intensity sites. The product of rate-of-spread, the amount of fuel consumed, and the heat content of wood (450 cal/gm) yields fire line intensity. Flame length averaged 0.9 m, with a range of 0.1 to 1.7 m. Percent area burned and duff reduction was measured the first season after treatment.

Vegetational development was measured for 3 consecutive years after treatment by monitoring permanent plots. Five 10 m transects were located in each 15 x 15 m macro-plot. Shrub canopy coverage was measured by the line intercept method (Canfield 1941). Herbaceous canopy coverage and frequency was measured by permanently locating ten 20 x 50 cm microplots along each of the 5 shrub transects. Cover was estimated using canopy

coverage classes (Daubenmire 1959). Frequency for shrub and tree seedlings was determined with the microplots. Duff depth was measured in the outer left corner of each microplot. Taxonomy of plant species follows Hitchcock and Cronquist (1973).

Jaccard's Index of Similarity (Mueller-Dumbois and Ellenberg 1974) was used to test for understory community differences among locations and treatments. Canopy coverage and frequency differences were analyzed with the Statistical Analysis System's (Helwig and Council 1979) ANOVA procedure. Duncan's Multiple Range Test ranked statistically significant means. The level of significance was set at 90 percent.

RESULTS

The effect of fire intensity on plant response cannot be separated from the preburn community (Lyon and Stickney 1977). The 3 locations studied were very similar in species composition and abundance. The rich array of species was the result of disturbance by logging and fire and because the sampled sites were on the mesic end of the habitat type. Five shrubs, 4 perennial graminoids, 8 perennial forbs, and 4 annuals displayed significant differences in canopy coverage among treatments. All of these species had canopy coverage values less than 5 percent; therefore, successional trends of individual species could not be drawn.

Canopy coverage for graminoids was significantly lower on high intensity sites (Fig. 1). Cover decreased from 20.4 percent on unburned sites to 10.9 percent on high intensity sites. Conversely, there was no significant difference in canopy coverage for shrubs or forbs among treatments. Shrub coverage ranged from 27 percent on high intensity sites, 23 percent on low intensity sites, and 31 percent on unburned sites. Forb coverage averaged 20, 25, and 17 percent, respectively, on similarly treated sites.

Canopy coverage for graminoids significantly increased from the first through the third year after treatment (Fig. 2). An abnormally large increase in coverage was observed between the first and second year. Likewise, canopy coverage for forbs was significant for

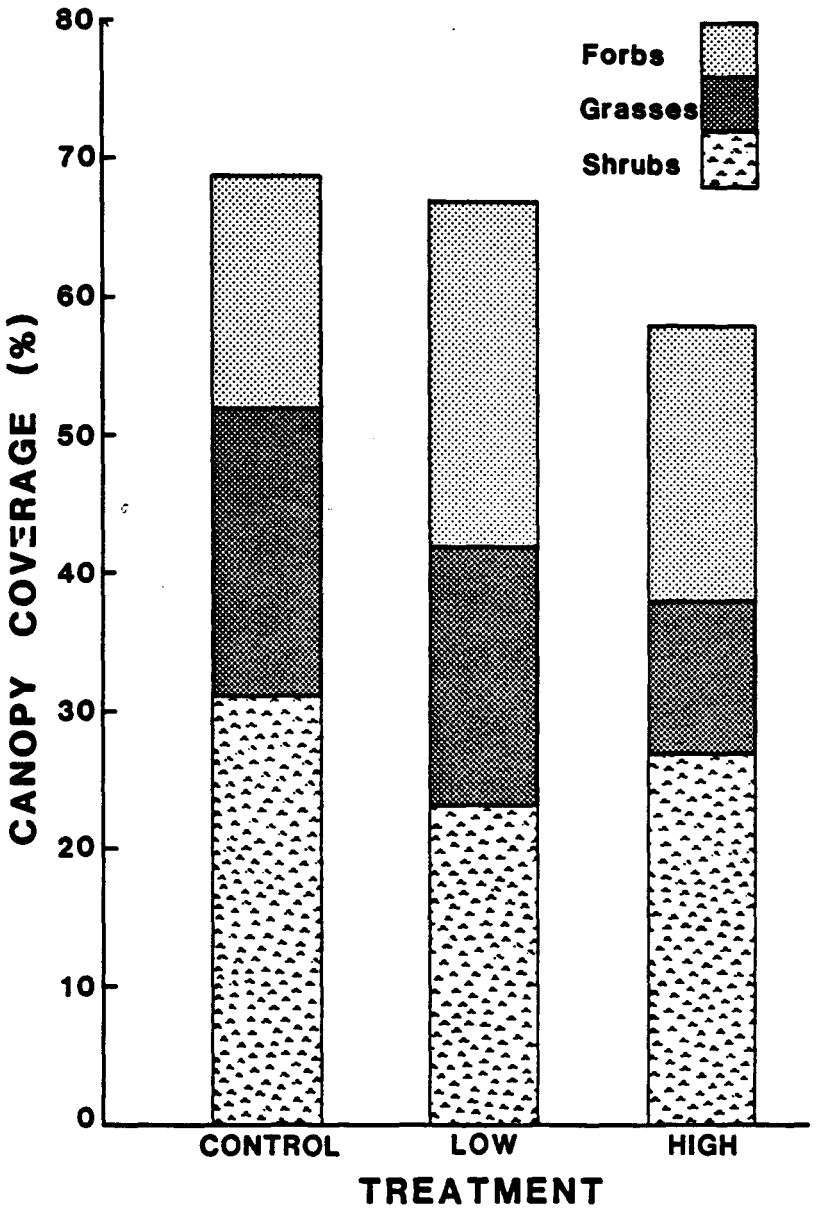

Figure 1. Mean canopy coverage of understory vegetation on unburned sites and sites treated with low and high intensity fires.

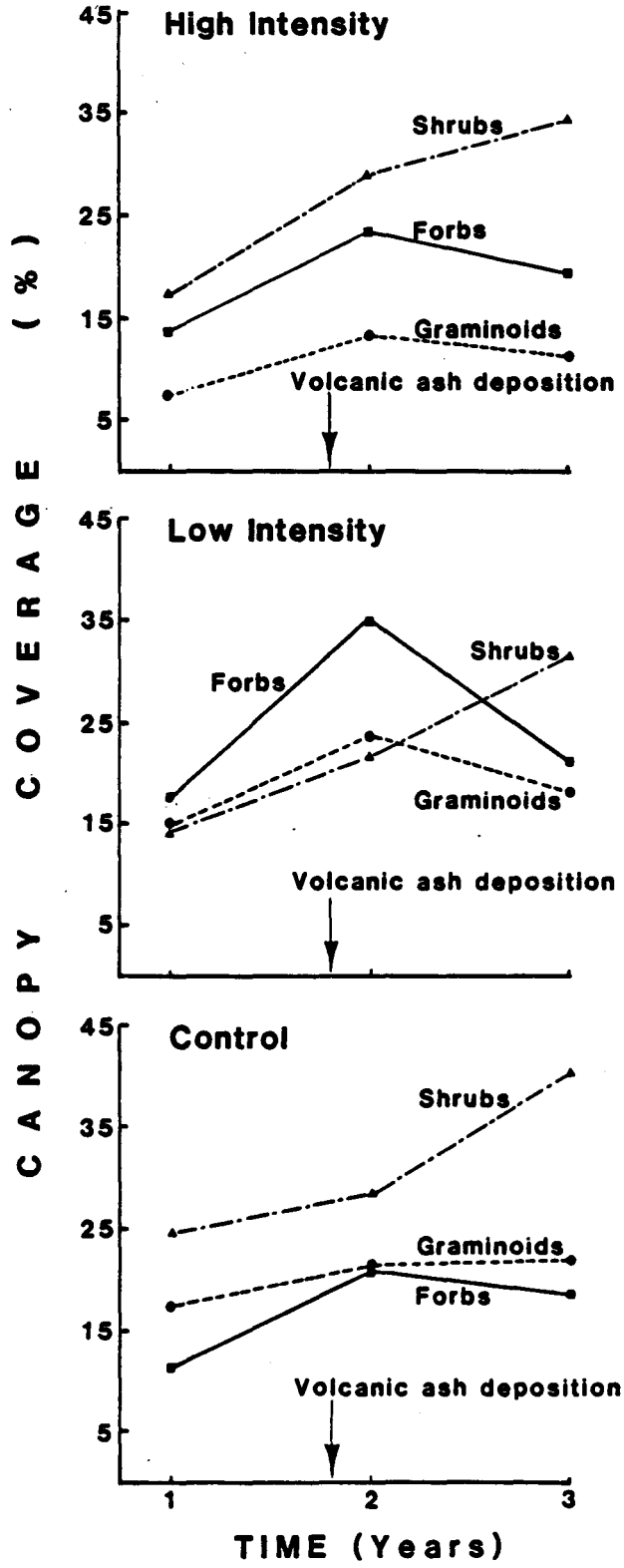

Figure 2. Mean canopy coverage of understory vegetation on unburned sites and sites treated with low and high intensity fires in relation to the number of years after treatment.

all 3 years and mimicked the pattern displayed by graminoids. Canopy coverage for shrubs significantly increased over the 3 year observation period.

A significant change in frequency among treatments was noted for 11 species (Fig. 3). Columbia brome (*Bromus vulgaris*) was the only common species harmed by fire. It was 2 to 5 times more frequent on unburned sites than high intensity sites. The difference between unburned sites and low intensity sites was much less. The other ten species were not always harmed by fire. Creeping Oregongrape (*Berberis repens*), field woodrush (*Luzula campestris*), and strawberry (*Fragaria virginiana*) were harmed on high intensity sites, but not on low intensity sites. Creeping Oregongrape was essentially absent from high intensity sites. Field woodrush was more than 7 times more frequent on unburned sites than high intensity sites. Strawberry was more than twice as common on unburned sites and low intensity sites than high intensity sites.

Conifer seedlings were essentially absent from all sampled sites. Redstem ceanothus (*Ceanothus sanguineus*) seedlings were more frequent on high intensity sites. No redstem ceanothus seedlings were recorded on either unburned sites or low intensity sites. Similarly, spreading dogbane (*Apocynum androsaemifolium*) was rare on sites other than high intensity sites. Fireweed (*Epilobium angustifolium*) was 2 to 5 times more common on high intensity sites than low intensity sites. It was extremely rare on unburned plots. Narrowleaf collomia (*Collomia linearis*) was commonly found on treated and untreated plots, but it was most common on high intensity sites. Frequency for unburned sites and low intensity sites ranged from 1 to 10 and 9 to 14 percent, respectively. Frequency for high intensity sites ranged from 10 to 37 percent.

Slender cinquefoil (*Potentilla gracilis*), prairie smoke avens (*Geum triflorum*), and American vetch (*Vicia americana*) were more common on low intensity sites than the other two sites. Mean frequency for slender cinquefoil ranged from 26 to 32 percent on low intensity sites, 7 to 11 percent on high intensity sites, and 18 to 22 percent on unburned sites. Frequency for prairie smoke avens and American vetch was from 2 to 4 and 7 to 11 times greater on low intensity sites than on unburned sites or high intensity sites.

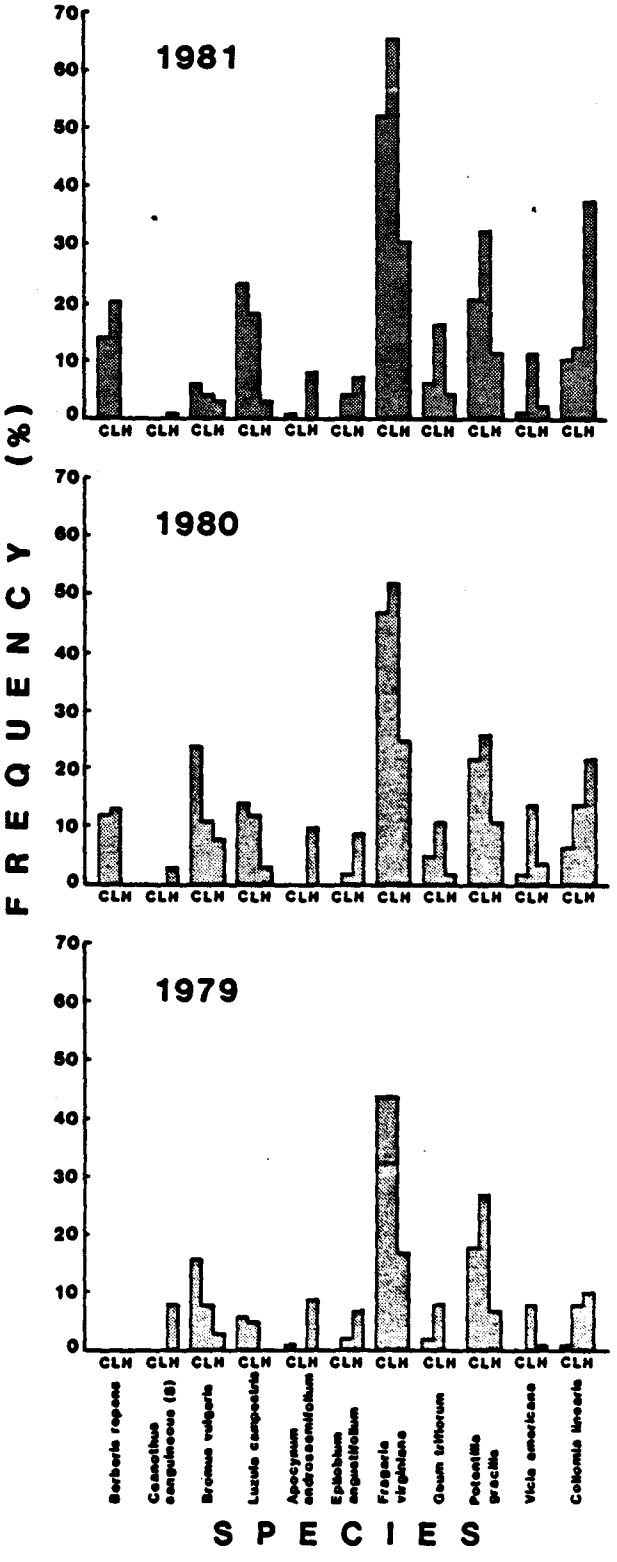

Figure 3. Mean frequency of selected understory species on unburned sites, and sites treated with low and high intensity fires in relation to the number of years after treatment.

There was a significant difference in frequency from the first through the third growing season for 9 of the above 11 species. Only redstem ceanothus seedlings exhibited a decrease in frequency during the course of the study. Field woodrush, strawberry, prairie smoke avens, slender cinquefoil, and narrow-leaf collomia increased over the observation period. The increase in frequency for Columbia brome and American vetch was followed by a decline.

DISCUSSION

The reduction in canopy coverage for graminoids on high intensity sites was apparently the result of prolonged smoldering, which destroyed root crowns and rhizomes. A significantly greater proportion of duff was removed on high intensity sites. Duff depth for high intensity sites was 1.3 cm, 4.0 cm on low intensity sites, and 6.6 cm on unburned sites. Duff depth means were relatively uniform (C.V. = 38.1), however, samples were highly variable (0 to 14 cm). Site inspection the day after treatment revealed that the organic material on high intensity sites continued to smolder. Combustion on low intensity sites was not as complete as on the high intensity sites. Graminoid response appeared to vary with the amount of duff burned regardless of the fire line intensity. For example, the fire on one low intensity site had an average flame length of 1.2 m, a rate of spread of 0.9 m/min, little downed woody fuel consumed, an intensity of 148 kcal/m-s, yet average 4.5 cm of duff removed. On a high intensity site, the flame length was 0.5 m, the backing rate of spread was 0.3 m/min, woody fuel consumed was 2.1 kg/m^2, the fire line intensity was 130 kcal/m-s, and the amount of duff removed was 4.8 cm. Thus canopy coverage for perennial graminoids is apparently dependent on the depth of the duff and independent of fire line intensity.

Canopy coverage for shrubs was unaffected by treatment. There was no change in cover among treatments for snowberry (*Symphoricarpos albus*) (Table 1), the dominant shrub on the sampled plots. This may have masked the response of other, less abundant,

Table 1. Mean canopy coverage and frequency[1] of understory species on 27 selectively logged, broadcast burned sites in the Douglas-fir/ ninebark habitat type. Mean fire line intensity for low intensity sites was 127 Kcal/m-s and 781 Kcal/m-s for high intensity sites.

	Treatment						Time since treatment (yrs)					
Species	Control		Low		High		1		2		3	
Shrubs												
Amelanchier alnifolia	0.5a[2]		0.2a		0.1a		0.1b		0.2b		0.4a	
Berberis repens	1.1a	8.6ab	1.2a	11.1a	0.0b	0.2b	0.0b	0.0b	1.1a	8.4a	1.3a	11.4a
Ceanothus sanguineus	0.2a		0.1a		0.8a		0.1b		0.2b		0.9b	
Crataegus douglasii	1.0a		0.0a		0.2a		0.4a		0.2a		0.8a	
Holodiscus discolor	3.9a		1.0a		2.7a		1.7b		1.9b		3.9a	
Physocarpus malvaceus	2.0a		0.0b		0.4b		0.5a		0.9a		1.0a	
Prunus emarginata	0.0a		0.0a		0.1a		0.0a		0.0a		0.1a	
P. virginiana	3.7a		5.0a		2.1a		3.3a		3.6a		3.9a	
Rosa gymnocarpa	3.1a		0.6b		0.9b		1.2b		1.1b		2.2a	
R. nutkana	0.5a		0.1a		0.2a		0.0b		0.1b		0.7a	
R. woodsii	0.8a		0.7a		0.2b		0.6a		0.8a		0.4a	
Salix scouleriana	0.1b		1.1a		0.0b		0.2a		0.5a		0.2a	
Spiraea betulifolia	0.6a		1.8a		2.1a		1.4a		2.0a		1.0a	
Symphoricarpos albus	17.3a		14.3a		20.4a		11.4c		18.2b		22.5a	
S. mollis	0.0a		0.0a		1.0a		0.0a		0.9a		0.0a	
Perennial graminoids												
Agropyron spicatum	1.4a	25.7a	2.1a	30.4a	0.8a	11.8a	1.3b	22.7a	1.7a	23.6a	1.3b	21.5a
Bromus vulgaris	0.7a	15.5a	0.3b	7.7b	0.3b	4.6b	0.5a	9.1b	0.7a	14.5a	0.2b	4.2c
Calamagrostis rubescens	29.1a	44.0a	27.8a	48.1a	16.1a	25.7a	22.4a	40.5a	26.2a	41.6a	24.6a	35.7b
Elymus glaucus	2.7a	46.1a	1.7a	36.4a	1.2a	24.4a	1.5b	27.3c	2.1a	34.1b	2.0a	45.5a
Festuca idahoensis	1.9a	24.8a	1.0a	20.4a	0.4a	10.8a	0.6c	11.7c	1.0b	16.1b	1.6a	28.3a
F. scabrella	0.0b	0.6a	0.6a	5.3a	0.2ab	2.1a	0.3b	2.4ab	0.1c	1.2b	0.4a	4.3a
Luzula campestris	0.5a	14.5a	0.4a	11.6a	0.1b	2.0b	0.1b	3.9c	0.4a	9.6b	0.4a	14.7a
Poa spp.	2.8a	29.0a	2.1a	29.3a	1.8a	22.2a	1.0c	18.4b	3.3a	30.4a	2.2b	31.8a
Trisetum canescens	0.8c	21.2a	0.5b	15.6b	0.2c	5.7c	0.1c	3.9b	0.4b	8.7b	0.9a	30.0a

Table 1. (Continued)

Species	Treatment						Time since treatment (yrs)					
	Control		Low		High		1		2		3	
Perennial forbs												
Achillea millefolium	1.0a	28.2a	1.3a	28.3a	0.5a	12.1a	0.7a	18.8b	1.4b	24.8a	0.7a	25.0a
Anemoni piperi	0.0a	1.9a	0.1a	3.3a	0.1a	1.5a	0.0b	0.7b	0.2a	4.8a	0.1b	1.2b
Apocynum androsaemifolium	0.0b	0.7b	0.0b	0.1b	1.0a	9.2a	0.4a	3.5a	0.4a	3.5a	0.2a	3.0a
Arenaria macrophylla	1.3a	11.0a	2.1a	16.8a	0.6a	3.9a	1.5a	9.9a	1.8a	10.8a	0.9a	11.0a
Aster jessicae	0.3b	3.9b	2.2a	22.2a	1.0b	7.6b	0.8b	8.8c	1.7a	13.7a	1.0b	11.1b
Cirsium spp.	0.1b	1.0b	0.1b	2.8b	0.4a	8.7a	0.1b	1.0b	0.1b	2.2b	0.3a	9.3a
Epilobium angustifolium	0.0b	0.2b	0.3b	2.7ab	1.2a	7.6a	0.6a	3.0a	0.6a	3.8a	0.4a	3.6a
Fragaria virginiana	2.9ab	47.6a	3.4a	53.6a	1.6b	24.2b	1.5c	35.0c	4.1a	41.3b	2.3b	49.1a
Galium boreale	2.7a	24.4a	3.5a	25.3a	1.9a	13.0a	2.6a	20.5a	3.3a	20.4a	2.2a	21.9a
Geranium viscosissimum	0.9a	12.7a	1.7a	17.9a	1.1a	11.3a	0.6c	8.2b	1.9a	17.3a	1.3b	16.4a
Geum triflorum	0.3b	4.2b	0.8a	11.8a	0.1b	2.3b	0.2b	3.4b	0.5a	6.0b	0.5a	8.9a
Hieracium albiflorum	0.7a	2.7a	0.8a	3.7a	0.4a	1.9a	0.4a	1.8a	0.9a	3.8a	0.3a	2.7a
Lathyrus bijugatus	0.7a	13.9a	0.4a	11.0a	0.6a	12.0a	0.6b	11.8b	0.8a	15.6a	0.2c	9.4b
Lomatium triternatum	0.4a	4.5a	0.4a	3.6a	0.4a	3.6a	0.1a	3.2a	0.4a	4.7a	0.3a	3.9a
Lupinus spp.	0.1a	1.4a	0.6a	6.9a	0.4a	5.4a	0.4a	4.4a	0.5a	5.6a	0.2b	3.7a
Osmorhiza chilensis	0.1a	2.7a	0.2a	5.6a	0.2a	4.8a	0.1b	1.6b	0.2a	5.6a	0.2a	6.1a
Penstemon spp.	0.5a	6.2a	0.2a	3.3a	0.0a	1.2a	0.1b	3.4ab	0.5a	6.1a	0.1b	1.1b
Potentilla glandulosa	0.4a	5.6a	0.4a	5.1a	0.0a	0.6a	0.3ab	4.5a	0.4a	3.7a	0.2b	3.0a
P. gracilis	1.4ab	20.2c	2.2a	31.6a	0.8b	10.2b	1.1b	18.0b	2.2a	23.1a	1.1b	20.8ab
Pteridium aquilinum	1.3a	6.5a	2.3a	8.9a	2.5a	8.7a	1.1c	5.1a	2.0b	8.3a	3.0a	10.6a
Solidago canadensis	0.5a	3.2a	1.1a	6.2a	0.1a	0.9a	0.2a	1.7b	0.5a	2.0b	1.0a	6.5a
Stellaria spp.	0.6a	4.4a	0.6a	5.9a	1.2a	11.7a	0.4a	4.5a	1.1a	7.3a	0.9a	10.4a
Taraxacum officinale	0.1a	3.6a	0.1a	3.3a	0.2a	4.3a	0.1b	1.3b	0.3a	7.6a	0.1b	2.4b
Trifolium latifolium	1.9a	25.5a	1.2a	18.4a	2.3a	20.1a	2.1a	24.3a	2.8a	29.3a	0.4b	10.3b
Vicia americana	0.1b	1.2b	0.7a	11.1a	0.1b	2.1b	0.2a	3.0b	0.5a	6.8a	0.1a	4.5b

Table 1. (Continued)

Species	Treatment						Time since treatment (yrs)					
	Control		Low		High		1		2		3	
Annuals												
Bromus japonicus	0.1a	3.6a	0.1a	1.6a	0.1a	2.6a	0.0b	0.3b	0.0b	1.0b	0.2a	6.5a
Collinsia parviflora	0.1b	3.0b	0.1b	2.3b	0.4a	11.5a	0.0c	0.3b	0.3a	9.4a	0.2b	7.0a
Collomia linearis	0.2b	6.8b	0.4b	11.3b	0.9a	22.9a	0.3b	6.2b	0.6a	14.8a	0.5a	20.0a
Epilobium paniculatum	0.1b	2.4b	0.2b	5.9b	1.3a	27.3a	0.0b	0.3c	0.7a	9.8b	0.9a	15.5a
Foeniculum vulgare	0.2a	5.0a	0.3a	7.8a	0.4a	8.7a	0.1b	2.4b	0.5a	14.8a	0.1b	2.3b
Lactuca serriola	0.0b	1.2b	0.1b	2.7b	0.8a	17.5a	0.1b	1.1b	0.7a	11.9a	0.2b	8.3a

[1] Number to the left is percent coverage; the number to the right is percent frequency.
[2] Means with a row followed by same letters are not significantly different ($P \leq 0.1$).

shrubs. The response illustrated in Figure 2 implies that fires that consume only a small portion of the duff layer, favors site occupancy by herbaceous plants.

The lack of change in canopy coverage for forbs among treatments may be attributed to the size of the sampled sites, their arrangement, and the nonuniform fire behavior on fire treated sites. Because the sites ranged from 0.2 to 1.0 ha in size, and were positioned adjacent to one another (Bakken 1981), wind-borne propagules were available to all of the sites, regardless of the treatment. Jaccard's Index of Similarity for unburned plots versus plots treated with high intensity fires ranged from 73 to 82 percent. This implies that the flora on differentially treated sites was similar.

An 11 to 35 percent reduction in overstory basal area stimulated a continual increase in shrub canopy coverage over a 3 year period. An increase in the amount of light striking the forest floor, together with decreased competition for moisture between shrubs and trees, enabled the shrub layer to expand. A similar phenomenon was noted in mountain pine beetle (*Dendroctonus pseudotsugae*) killed stands of lodgepole pine (*Pinus contorta*) (Armour 1982). Apparently, competition for moisture and light was reduced with the death of the overstory.

The pattern exhibited by grasses and forbs was very different from the observed recovery pattern for shrubs. One would expect a continual increase in canopy coverage for both over a 3 year period. In broadcast burned clearcuts, Zamora (In press) reported that the greatest increase in total canopy coverage occurred between the second and third year after burning. The 10 cm layer of volcanic ash from the May 18, 1980, eruption of Mt. St. Helens may have been responsible for the abnormal response observed in this study. The yield for 3 cultivated grains (Fig. 4) near Farmington, Washington, (located approximately 28 km southwest of the study area) was similar to the response exhibited by the herb layer. Evidently, the ash cap served as a lid that sealed the soil surface and effectively reduced the evaporative component of the water budget. Thus, the abrupt increase in cover may have been the result of an increase in available moisture in the upper soil profile. This cap effect was broken up by the following year, and was not apparent in 1981.

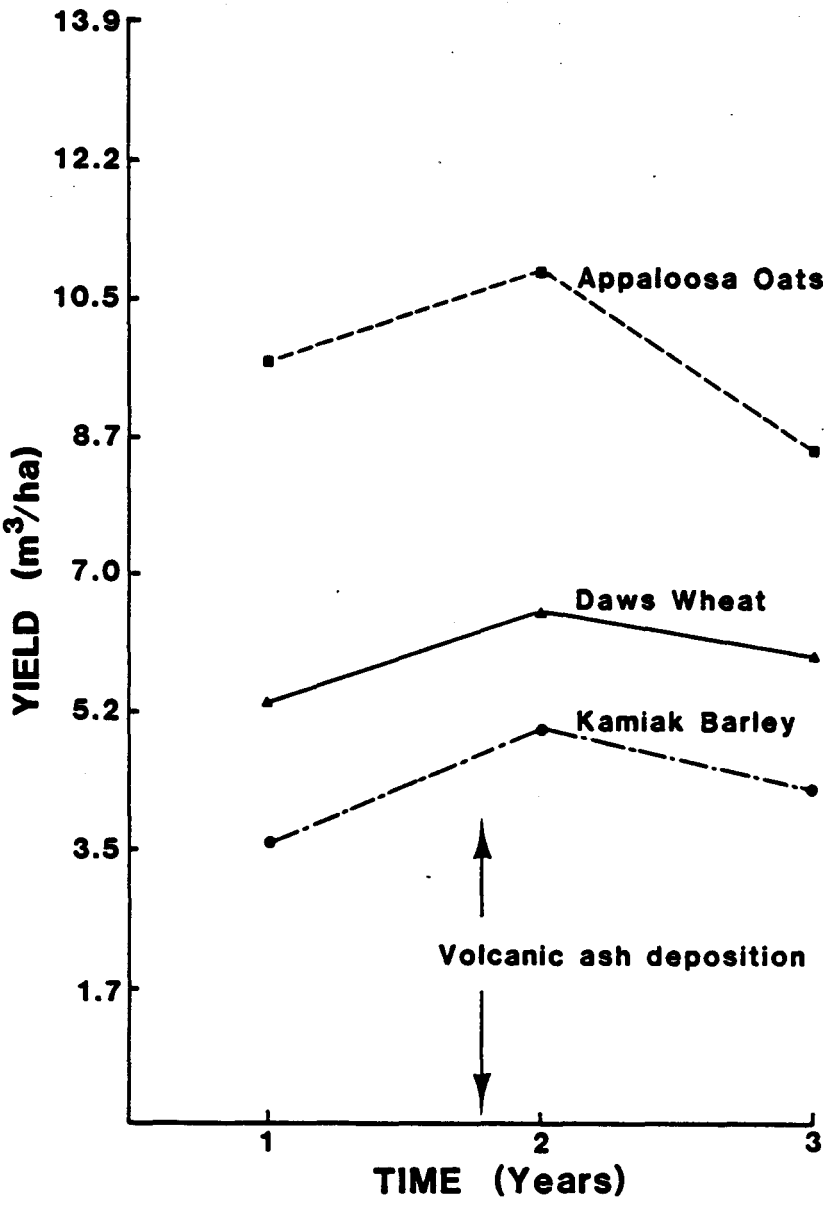

Figure 4. The 1979, 1980, and 1981 yield of 3 cultivated grains near Farmington, Washington.

Two conclusions may be drawn from the results of this study. First, the most important factor in studying vegetational change following understory burning is the preburn plant community. A change in species composition and abundance may have gone undetected because the burned sites were not sampled prior to ignition. Therefore, it is necessary to sample the vegetation before ignition. Second, the change in graminoid abundance was related to the amount of duff consumed, and independent of fire line intensity and flame length. Thus, when studying vegetation changes in response to understory burning, one should concentrate on the fuel consumed, rather than the fire behavior at the time of the burn.

LITERATURE CITED

Armour, C. D. 1982. Fuel and vegetation succession in response to mountain pine beetle epidemics. M.S. Thesis, Univ. of Idaho, Moscow. 42 p.

Bakken, S. 1981. Predictions of fire behavior, fuel reduction, and tree damage from understory prescribed burning in the Douglas-fir/ninebark habitat type of northern Idaho. M.S. Thesis, Univ. of Idaho, Moscow. 137 p.

Biswell, H. H., H. R. Kallander, R. Komarack, R. J. Vogl, and H. Weaver. 1973. Ponderosa fire management. Tall Timbers Res. Stn. Misc. Publ. 2. Tallahassee, FL. 49 p.

Canfield, H. R. 1941. Application of the line intercept method in sampling range vegetation. J. For. 39:388-394.

Cattelino, P. J., I. R. Noble, R. O. Slatyer, and S. R. Kessell. 1979. Predicting the multiple pathways of plant succession. Environ. Manage. 3:41-50.

Daubenmire, R. 1959. A caonpy-coverage method of vegetation analysis. Northwest Sci. 33:43-66.

Daubenmire, R., and J. B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Wash. St. Ag. Exp. Stn. Tech. Bull. No. 60. 104 p.

Fling, H. R. 1925. Fire resistance of northern Rocky Mountain conifers. Idaho Forester 7:7-10, 41-43.

Helwig, J. T. and K. A. Council, eds. 1979. SAS users guide 1979 edition. SAS Institute Inc., Raleigh, NC. 494 p.

Hitchcock, C. L. and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Wash. Press, Seattle. 730 p.

Hooker, L. L. 1972. Effects of prescribed burning on soils and vegetation of seral brush communities in the Lochsa River region of northern Idaho. M.S. Thesis, Univ. of Idaho, Moscow. 75 p.

Keown, L. D. 1978. Fire management in the Selway-Bitterroot Wilderness, Moose Creek Ranger District, Nezperce National Forest. USDA For. Serv. 168 p.

Larsen, J. A. 1929. Fires and forest succession in the Bitterroot Mountains of northern Idaho. Ecology 10:67-76.

Leege, T. A. 1968. Prescribed burning for elk in northern Idaho. Tall Timbers Fire Ecol. Conf. Proc. 8:235-253.

Lyon, L. J. 1971. Vegetal development following prescribed burning of Douglas-fir in south central Idaho. USDA For. Serv. Res. Pap. INT-105. 30 p.

Lyon, L. J. and P. F. Stickney. 1976. Early vegetal succession following large Rocky Mountain wildfires. Tall Timbers Fire Ecol. Conf. Proc. 14:355-373.

Mueller-Dumbois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. J. Wiley & Sons, New York. 547 p.

Rothermel, R. C. 1972. A mathematical model for predicting fire spread in wildland fuels. USDA For. Serv. Res. Pap. INT-115. 40 p.

Schubert, G. H. 1974. Silviculture of southwestern ponderosa pine: The state of our knowledge. USDA For. Serv. Res. Pap. RM-23. 71 p.

Schultz, A. M. and H. H. Biswell. 1959. Effect of prescribed burning and other seedbed treatments on ponderosa pine seedling emergence. J. For. 57:816-817.

Wright, H. A. 1978. The effects of fire on vegetation in ponderosa pine forests. A state-of-the-art review. Texas Tech Univ., Coll. Ag. Sci. Publ. T-9-199, Lubbock, TX. 21 p.

Wright, H. A., and A. W. Bailey. 1982. Fire ecology: United States and southern Canada. J. Wiley & Sons, New York. 501 p.

Zamora, B. A. In press. Understory development in forest succession: An example from the Inland Northwest. *In* Northwest Sci. Proc. of a Symp. on Forest Succession, 1981. PNW For. and Range Exp. Stn., Corvallis, OR.